WHAT IS CLAIMED IS:

1. A catadioptric optical system forming a reduced image of a first surface onto a second surface comprises:

a first imaging optical subsystem which is arranged in an optical path between the first surface and the second surface and has a dioptric imaging optical system to form a first intermediate image of the first surface;

a first folding mirror which is arranged in the vicinity of a position of forming the first intermediate image to deflect a beam prior to or after the position where the first intermediate image is formed;

a second imaging optical subsystem for forming a second intermediate image with a magnification factor nearly equal to the first intermediate image in the vicinity of a position of forming the first intermediate image based on the beam from the first intermediate image, the second image optical subsystem has a concave reflecting mirror and at least one negative lens;

a second folding mirror which is arranged in the vicinity of a position of forming the first intermediate image to deflect a beam prior to or after the position where the second intermediate image is formed; and

a third imaging optical subsystem which is arranged in an optical path between the second imaging optical subsystem and the second surface and has a dioptric imaging optical system to form the reduced image onto the second surface based on the beam from the second intermediate image.

2. The catadioptric optical system of Claim 1, wherein a reflecting surface of the first folding mirror and a reflecting surface of the second folding mirror are positioned so that they do not overlap spatially.

3. The catadioptric optical system of Claim 2, wherein all lenses constituting the first imaging optical subsystem and all lenses constituting the third imaging optical subsystem are arranged along a single optical axis.

4. The catadioptric optical system of Claim 3, wherein a magnification factor $\beta 2$ of the second imaging optical subsystem satisfies the following condition:

$$0.82 < |\beta 2| < 1.20.$$

5. The catadioptric optical system of Claim 4, wherein the following condition is satisfied:

$$|L1-L2| / |L1| < 0.15,$$

where a first distance between the first intermediate image and the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as L1, and a second distance between the second intermediate image and the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as L2.

6. The catadioptric optical system of Claim 5, wherein the following condition is satisfied:

$$0.20 < |\beta| / |\beta 1| < 0.50,$$

where a magnification of the catadioptric optical system is defined as β, and a magnification of the first imaging optical subsystem is defined as $\beta 1$.

7. The catadioptric optical system of Claim 6, wherein the catadioptric optical system is a telecentric optical system on both sides of the first surface and the second surface, and satisfies the following condition:

$$|E - D| / |E| < 0.24,$$

where a distance between a surface of the first imaging optical subsystem on a most image side and an exit pupil position along the optical axis is defined as E, and a distance by air conversion from the surface of the first imaging optical subsystem on the most image side to the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as D.

8. The catadioptric optical system of Claim 7, wherein:

the first intermediate image is formed in an optical path between the first folding mirror and the second imaging optical subsystem, and

the second intermediate image is formed in an optical path between the second imaging optical subsystem and the second folding mirror.

9. The catadioptric optical system of Claim 8, wherein:

85% of the number of lenses in all lenses constituting the catadioptric optical system are arranged along the single optical axis.

10. The catadioptric optical system of Claim 9, wherein:

an intersection line of an extension plane of the reflecting surface of the first folding mirror and an extension plane of the reflecting surface of the second folding mirror is set up so that an optical axis of the first imaging optical subsystem, an optical axis of the second imaging optical subsystem and an optical axis of the third imaging optical subsystem intersect at one point.

11. The catadioptric optical system of Claim 10, wherein:

the second imaging optical subsystem has at least two negative lenses.

12. The catadioptric optical system of Claim 11, wherein:

the first folding mirror has a back surface reflecting mirror for reflecting a beam from the first imaging optical subsystem to the second imaging optical subsystem, and

the second folding mirror has a back surface reflecting mirror for reflecting a beam from the second imaging optical subsystem to the third imaging optical subsystem.

13. The catadioptric optical system of Claim 12, wherein:

the catadioptric optical system forms the reduced image on a position deviating from a position of reference in an optical axis of the catadioptric optical system on the second surface.

14. The catadioptric optical system of Claim 1, wherein:

a plurality of lenses constituting the first imaging optical subsystem and a plurality of lenses constituting the third imaging optical subsystem are arranged along a single optical axis.

15. The catadioptric optical system of Claim 1, wherein a magnification $\beta 2$ of the second imaging optical subsystem satisfies the following condition:

$$0.82 < |\beta 2| < 1.20.$$

16. The catadioptric optical system of Claim 1, wherein the following condition is satisfied:

$$|L1 - L2| / |L1| < 0.15,$$

where a first distance between the first intermediate image and the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as L1, and a second distance between the second intermediate image and the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as L2.

17. The catadioptric optical system of Claim 1, wherein the following condition is satisfied:

$$0.20 < |\beta| / |\beta 1| < 0.50,$$

where a magnification of the catadioptric optical system is defined as β, and a magnification of the first imaging optical subsystem is defined as $\beta 1$.

18. The catadioptric optical system of Claim 1, wherein the catadioptric optical system is a telecentric optical system on both sides of the first surface and the second surface, and satisfies the following condition:

$$|E - D| / |E| < 0.24,$$

where a distance between a surface of the first imaging optical subsystem on a most image side and an exit pupil position along the optical axis is defined as E, and a distance by air conversion from the surface of the first imaging optical subsystem on the most image side to the concave reflecting mirror in the second imaging optical subsystem along the optical axis is defined as D.

19. The catadioptric optical system of Claim 1, wherein:

the first intermediate image is formed in an optical path between the first folding mirror and the second imaging optical subsystem, and

the second intermediate image is formed in an optical path between the second imaging optical subsystem and the second folding mirror.

20. The catadioptric optical system of Claim 1, wherein:

the first intermediate image is formed in an optical path between the first folding mirror and the second imaging optical subsystem, and

the second intermediate image is formed in an optical path between the second imaging optical subsystem and the second folding mirror.

21. The catadioptric optical system of Claim 1, wherein:

85% of the number of lenses in all lenses constituting the catadioptric optical system are arranged along the single optical axis.

22. The catadioptric optical system of Claim 1, wherein an intersection line of an extension plane of a reflecting surface of the first folding mirror and an extension plane of a reflecting surface of the second folding mirror is set up so that an optical axis of the first imaging optical subsystem, an optical axis of the second imaging optical subsystem and an optical axis of the third imaging optical subsystem intersect at one point.

23. The catadioptric optical system of Claim 1, wherein the second imaging optical subsystem has at least two negative lenses.

24. The catadioptric optical system of Claim 1, wherein:

the first folding mirror has a back surface reflecting surface for reflecting a beam from the first imaging optical subsystem to the second imaging optical subsystem, and

the second folding mirror has a back surface reflecting surface for reflecting a beam from the second imaging optical subsystem to the third imaging optical subsystem.

25. The catadioptric optical system of Claim 1, wherein:

the catadioptric optical system forms the reduced image in a position deviating from a position of a reference optical axis of the catadioptric optical system on the second surface.

26. A catadioptric optical system forming a reduced image on second surface comprises:

a first imaging optical subsystem with a first optical axis, which is arranged in an optical path between the first surface and the second surface and has a dioptric imaging optical system;

a second imaging optical subsystem with a concave reflecting mirror and a second optical axis, which is arranged in an optical path between the first imaging optical subsystem and the second surface; and

a third imaging optical subsystem with a third optical axis, which is arranged in an optical path between the second imaging optical subsystem and the second surface and has a dioptric imaging optical system,

where the first optical axis and the second optical axis intersect with each other and the second optical axis and the third optical axis intersect with each other.

27. A catadioptric optical system forming a reduced image on second surface comprises:

a first imaging optical subsystem with a first optical axis, which is arranged in an optical path between the first surface and the second surface and has a dioptric imaging optical system;

a second imaging optical subsystem with a concave reflecting mirror and a second optical axis, which is arranged in an optical path between the first imaging optical subsystem and the second surface; and

a third imaging optical subsystem with a third optical axis, which is arranged in an optical path between the second imaging optical subsystem and the second surface and has a dioptric imaging optical system,

where the first optical axis and the third optical axis are located on a common axis.

28. A projection exposure apparatus comprises:

a projection optical system which is arranged in an optical path between first surface and second surface that projects and exposes a pattern on a negative plate located on a first surface onto a workpiece located on the second surface, and

the projection optical system comprises:

a first imaging optical subsystem having a dioptric imaging optical system;

a second imaging optical subsystem having a concave reflecting mirror;

a third imaging optical subsystem having a dioptric imaging optical system;

a first folding mirror arranged in an optical path between the first imaging optical subsystem and the second imaging optical subsystem; and

a second folding mirror arranged in an optical path between the second imaging optical subsystem and the third imaging optical subsystem;

where the first imaging optical subsystem forms a first intermediate image of the first surface into the optical path between the first imaging optical subsystem and the second imaging optical subsystem, and the second imaging optical subsystem forms a second intermediate image of the first surface into the optical path between the second imaging optical subsystem and the third imaging optical subsystem.

29. The projection exposure apparatus of Claim 28, wherein:

the projection exposure apparatus projects the pattern on the negative plate onto the workpiece and exposes the pattern while the negative plate and the workpiece are moved in the same direction.

30. The projection exposure apparatus of Claim 29, wherein:

the first folding mirror has a first reflecting surface,

the second folding mirror has a second reflecting surface, and

the first reflecting surface and the second reflecting surface are positioned so that they do not overlap spatially.

31. The projection exposure apparatus of Claim 30, wherein:

the first and the second reflecting surfaces are substantially flat surfaces.

32. The projection exposure apparatus of Claim 29, wherein:

the projection optical system forms a reduced image of the pattern onto the workpiece.

33. The projection exposure apparatus of Claim 29, wherein:

at least one of the first imaging optical subsystem and the third imaging optical subsystem contains an aperture stop.

34. The projection exposure apparatus of Claim 29, wherein:

a plurality of optical members in the first imaging optical subsystem are arranged along a first optical axis extending in a straight line,

the concave reflecting mirror in the second imaging optical subsystem are arranged along a second optical axis, and

a plurality of optical members in the third imaging optical subsystem are arranged along a third optical axis extending in a straight line.

35. The projection exposure apparatus of Claim 29, wherein:

the first imaging optical subsystem and the third imaging optical subsystem have a common optical axis, and

the first surface and the second surface are orthogonal in a direction of gravity.

36. The projection exposure apparatus of Claim 29, wherein a magnification $\beta 2$ of the second imaging optical subsystem satisfies the following condition:

$$0.82 < |\beta 2| < 1.20.$$

37. The projection exposure apparatus of Claim 29, wherein the following condition is satisfied:

$$0.20 < |\beta| / |\beta 1| < 0.50$$

wherein a magnification of the projection optical system is defined as β, and a magnification of the first imaging optical subsystem is defined as $\beta 1$.

38. The projection exposure apparatus of Claim 29, wherein:

the projection optical system has a telecentric optical system on the side of first surface and on the side of second surface, and

a concave reflecting mirror in the second imaging optical subsystem is arranged in the vicinity of a pupil surface of the projection optical system.

39. The projection exposure apparatus of Claim 29, wherein:

the first intermediate image is formed in the optical path between the first folding mirror and a concave reflecting mirror in the second imaging optical subsystem, and

the second intermediate image is formed in the optical path between the concave reflecting mirror in the second imaging optical subsystem and the second folding mirror.

40. The projection exposure apparatus of Claim 39, wherein:

the first intermediate image and the second intermediate image are formed in both sides of a second optical axis of the second imaging optical subsystem.

41. The projection exposure apparatus of Claim 29, wherein:

a second optical axis of the second imaging optical subsystem is orthogonal to a first optical axis of the first imaging optical subsystem and a third optical axis of the third imaging optical subsystem.

42. The projection exposure apparatus of Claim 41, wherein:

the second optical axis of the second imaging optical subsystem extends in a straight line.

43. The projection exposure apparatus of Claim 29, wherein:

an intersection line of an extension plane of a reflecting surface of the first optical path folding mirror and an extension plane of a reflecting surface of the second optical path folding mirror intersects with a first optical axis of the first imaging optical subsystem, a second optical axis of the second imaging optical subsystem and a third optical axis of the third imaging optical subsystem at one point.

44. The projection exposure apparatus of Claim 29, wherein:

the first folding mirror has a back surface reflecting surface for reflecting a beam from the first imaging optical subsystem to the second imaging optical subsystem, and

the second folding mirror has a back surface reflecting surface for reflecting a beam from the second imaging optical subsystem to the third imaging optical subsystem.

45. The projection exposure apparatus of Claim 29, wherein an image of the first surface is formed in a position deviating from a position of a reference optical axis of the projection optical system on the second surface.

46. An exposure method for projecting a pattern on a negative plate onto a workpiece via a projection optical system comprises:

directing an illuminating light in the ultraviolet region to the pattern;

directing the illuminating light to a first imaging optical subsystem containing a dioptric imaging optical system via the pattern to form first intermediate image of the pattern of the projection negative plate;

directing the illuminating light from the first intermediate image to a second imaging optical subsystem containing a concave reflecting mirror to form a second intermediate image;

directing the illuminating a light from the second intermediate image to a third imaging optical subsystem containing a dioptric imaging optical system to form a second intermediate image;

deflecting the illuminating light from the first imaging optical subsystem by a first folding mirror arranged in an optical path between the first imaging optical subsystem and the second imaging optical subsystem; and

deflecting the illuminating light from the second imaging optical subsystem by a second folding mirror arranged in an optical path between the second imaging optical subsystem and the third imaging optical subsystem.

47. The exposure method of Claim 46, wherein:

the pattern on the negative plate is projected onto the workpiece and exposed while the negative plate and the workpiece are moved in the same direction for the projection optical system.

48. A manufacturing method of micro-devices comprises a lithographic process using the projection exposure apparatus of Claim 29.

49. An imaging optical system forming an image of a first surface onto a second surface comprises at least one reflecting surface arranged between the first surface and the second surface, and the reflecting surface comprises a metallic reflective film and a correction film which is arranged on the metallic reflective film and corrects a phase difference caused by a difference of deflected state possessed by a reflected light from the metallic reflective film.

50. The imaging optical system of Claim 49, wherein:

the correction film corrects an angular characteristic of the phase difference caused by the difference of deflected states possessed by the reflected light from the metallic reflective film so as to obtain a desired distribution.

51. The imaging optical system of Claim 50, wherein:

the correction film has a dielectric multilayer film.

52. The imaging optical system of Claim 51, wherein:

the metallic reflective film contains aluminum.

53. The imaging optical system of Claim 52, wherein:

the reflecting surface is arranged on an optical folding mirror for intersecting optical axes before and after the reflecting surface intersect with each other.

54. The imaging optical system of Claim 53, wherein the imaging optical system forms an image of the first surface onto the second surface based on a radiation of 200 nm. or less.

55. The imaging optical system of Claim 54, wherein:

the imaging optical system is characterized by forming the image of the first surface in a position deviating from a position of a reference optical axis of the imaging optical system on the second surface.

56. The imaging optical system of Claim 49, wherein:

the correction film has a dielectric multilayer film.

57. The imaging optical system of Claim 49, wherein:

the metallic reflective film contains aluminum.

58. The imaging optical system of Claim 49, wherein:

the reflecting surface is arranged on the optical folding mirror for intersecting optical axes before and after the reflecting surface intersect with each other.

59. The imaging optical system of Claim 49, wherein:

the imaging optical system forms an image of the first surface onto second surface based on a radiation of 200 nm. or less.

60. The imaging optical system of Claim 49, wherein:

the imaging optical system is characterized by forming the image of the first surface in a position deviating from a position of a reference optical axis of the imaging optical system on the second surface.

61. A projection exposure apparatus for projecting a pattern on a negative plate onto a workpiece and exposing the pattern using a projection optical system, the image of the negative plate arranged on first surface is projected onto the workpiece arranged on second surface and exposed using the imaging optical system of Claim 49 as the projection optical system.

62. A manufacturing method of micro-devices comprises:

a lithographic process using the projection exposure apparatus of Claim 61.

63. A projection exposure method for projecting a pattern on a negative plate onto a workpiece using a projection optical system and exposing the pattern comprises:

a process for projecting an image of the negative plate arranged on the first surface is projected onto the workpiece arranged on the second surface and exposing the pattern by using the imaging optical system of Claim 49 as the projection optical system.

64. A projection exposure apparatus for projecting a pattern on a negative plate arranged on a first surface onto a workpiece arranged on a second surface and for exposing the pattern, comprising:

a projection optical system having at least one reflecting member arranged in an optical path between the first surface and the second surface,

said reflecting member reflects a light so that a phase difference between a P polarized component and a S polarized component for the reflecting member substantially does not exist when the P polarized component and the S polarized component come to the photosensitive substrate.

65. A manufacturing method of micro-devices comprises:

a lithographic process using the projection exposure apparatus of Claim 64.

66. A projection exposure method for projecting and exposing a pattern on a negative plate arranged on a first surface onto a workpiece arranged on a second surface comprises:

projecting the pattern onto the workpiece and exposing the pattern with a light passing through at least one reflecting member, and

reflecting the light with a reflecting member so that a phase difference between a P polarized component and a S polarized component for the reflecting member substantially does not exist when the P polarized component and the S polarized component come to the sensitive substrate.